Patterns and driving forces behind (sustainable and non-sustainable) innovations.

Some highlights from economics and management research

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by

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Technical change

Angus Maddison's estimates of total World production of goods and services:

- **During 320 years preceding 1820: Increase by a factor 3**
- **During 180 years after 1820: Increase by a factor 60**

Recognition in the early 1960s:

This amazing growth cannot be explained by an increase in factors of production (labour, capital); it must be due to 'technical change' (whatever that may be …)

Technical change as the unexplained residual

Robert Solow's (1957):

80% of growth in the period 1909-1949 in the US cannot be explained by growth of labour or capital; it must be due to 'technical change'.

Problem:

"Technical Change" was a *Black Box*: The unexplained residual! Our coefficient of ignorance!

(Numerous refinements followed)

New questions:

- **Why has industrial capitalism been so successful?**
- **Which organization of economic activity is more conducive to innovation?**
- **Which factors drive or hamper innovation?**
- **Are some types of capitalism (e.g. the corporatist 'Rineland' model) better than others (e.g. the Anglo-Saxon 'free market' model)?**

Static versus dynamic efficiency

Change of focus in economics:

From the neo-classical question:

"Given available technologies, how can we allocate resources most efficiently?" (static efficiency)

… to the evolutionary question:

"How can we achieve fast technological progress?"

(dynamic efficiency)

Towards a "direct" investigation of technical change

Observations:

- **There are from time to time 'pervasive' (general purpose) technologies that become relevant to many sectors (steam, electricity, new materials, microprocessor).**
- **Innovations are rarely an isolated episode but are embedded in a 'technological trajectory'. Important are not only the major breakthroughs but also the innumerable adjustments and improvements that follow them.**

Towards a "direct" investigation of technical change

Observations:

- **Many firms are (far) distant from the best-practice frontier (Production possibility curve): There are significant differences in productivity between firms in the same industries.**

- **Successful innovation in one industry can depend on progress in other industries, requiring interaction with other parties (suppliers, clients, public research institutions).**

Towards a "direct" investigation of technical change

Observations:

- **History matters: Accumulation of knowledge requires learning and R&D investment (knowledge is not freely available to perfectly informed agents).**
- **Relevant knowledge is not just 'taken from the shelf', but is historically accumulated in a process of learning. Past choices determine what a firm 'is good at' and this limits future choices for diversification. It limits entry to and exit from markets.**

Towards a "direct" investigation of technical change

Observations:

- **Firms take decisions under uncertainty. Innovations are expensive, time-consuming and uncertain; they involve trial and error, failures and dead ends. This can lead to under-investment in risky projects.**
- **R&D projects involve indivisibilities: High fixed (and mostly: sunk) costs, negligible marginal costs (Implication: strong economies of scale enhance the emergence of dominant players).**

Towards a "direct" investigation of technical change

Observations:

- **Firms are not so free to choose; they can be 'locked-in' (in inferior technologies), due to 'sunk costs' related to standards.**

- **'Tacit' knowledge from practical experience (ill-documented; un-codified; 'in the finger tops' of people) can be crucial.**

Towards a "direct" investigation of technical change

Observations:

- **Innovation is triggered by bottlenecks; solving one bottleneck can lead to new bottlenecks 'upstream' or 'downstream' in the production column.**

- **There is no 'linear' sequence: Basic research→ applied research→ invention→ development→ production→ marketing.**

Towards a "direct" investigation of technical change

Observations:

- **Innovation often involves strong information asymmetries. Together with the sunk cost character of investment in knowledge, this offers wide opportunities for opportunistic behaviour, rent seeking and moral hazard (Implications for contracting-out!)**

Towards a "direct" investigation of technical change

Observations:

- **Markets tend towards under-investment in R&D since firms cannot fully appropriate innovation benefits ('positive externalities'). This is due to the 'public goods' character of technological knowledge (non-rival, non-excludable).**

Four types of goods:

Rival (exhaustible): If I use it, somebody else can not use it	**Private goods:** Food, Cars, Houses	**Common resources:** Fish in ocean, Forests, City parks
Non-rival (or non-depletion): My use is not in conflict with somebody else's use	**Natural monopolies:** Internet, cable TV	**Public goods:** Rule of law; public safety
	Excludable: No free riding! (Strong property rights)	**Non-excludable:** Easy free riding (Weak property rights)

Why does not everybody innovate?

- **Risk and uncertainty (technology, clients, competitors)?**
- **Appropriation of innovation benefits?**
- **'Sailing ship' effect?**
- **Technological opportunity (sector-specific factors)?**
- **Firm-specific knowledge/competencies? (path dependency due to accumulated 'tacit' knowledge)**
- **Economic inducements (bottlenecks, local demand, input prices, competitive rivalry)?**

Innovation models: Schumpeter I and II

<u>Schumpeter I</u> model:

"*Entrepreneurial model*": new firm foundation (e.g. in ICT, biotechnology); individual inventor-entrepreneur ("Garage business").

<u>Schumpeter II</u> model:

"*Routinized innovation model*": Incremental, stepwise innovations based on continuous accumulation of (tacit) knowledge; professionalized R&D labs in larger firms.

Five major technological trajectories:

- **Supplier-dominated innovators**
- **Scale-intensive innovators**
- **Science-based innovators**
- **Information-intensive innovators**
- **Specialized suppliers**

→ These five types of innovators differ substantially

Supplier-dominated innovators:

Typical sectors:

- **Agriculture, traditional manufacturing and services**

Main sources of technology:

- **Little R&D (rather process-oriented than product-related R&D); equipment bought from suppliers; production learning**

Main tasks of technology strategy:

- **Exploit non-technological advantages; adopt IT and other equipment offered by suppliers; respond flexibly to user needs.**

Scale-intensive innovators:

Typical sectors:

- **Bulk materials; consumer durables; automobiles; civil engineering**

Main sources of technology:

- **Production engineering; Production learning; suppliers; design offices**

Main tasks of technology strategy:

- **Managing safe and complex products and processes**
- **Managing incremental improvements; adopt best practices**

Science-based innovators:

Typical sectors:

- **Electronics, chemicals**

Main sources of technology:

- **R&D, basic research**

Main tasks of technology strategy:

- **Exploit economies of scope**
- **Exploit basic science; collaborate with universities**

Information-intensive innovators:

Typical sectors:

- **Finance, Retail, Publishing, Travel**

Main sources of technology:

- **Software and systems departments; suppliers**

Main tasks of technology strategy:

- **New products and services; design and operation of complex information processing systems; match IT-based opportunities with user needs**

Specialized suppliers:

Typical sectors:

- **Mechanical engineering; instruments; software**

Main sources of technology:

- **Design; advanced users**

Main tasks of technology strategy:

- **Monitor users and maintain strong links with lead users; match technologies to user needs**

Locating R&D: Corporate or divisional?

Corporate level:

- **Long time horizons; slow feedback loops; weak internal linkages; strong linkages to external knowledge sources; projects are relatively cheap**

Business unit level:

- **Short time horizons; fast learning feedback loops; strong internal linkages with production and marketing; projects are relatively expensive**

Locating R&D: Corporate or divisional?

Rules of thumb:

- **R&D supporting existing businesses should be located in established divisions**
- **R&D supporting new businesses should initially be located in central labs, then transferred to divisions for exploitation**
- **R&D supporting foreign production should be located close to foreign production (adaptation of products to local conditions).**
- **Distinction between *physical location* and *funding* unit!**

Location and funding of R&D: Corporate or divisional?

	Corporate-level performance: Interfaces with advances in generic S&T	**Divisional-level performance:** Interfaces with production, customers and suppliers
	Quadrant 1	**Quadrant 2**
Corporate-level funding: Benefits are corporate-wide	**Scanning external research; Assimilating and assessing radical new technologies**	**Commercializing radical new technologies; Exploiting inter-divisional synergies**
	Quadrant 3	**Quadrant 4**
Divisional-level funding: Benefits are division-specific	**Exploratory development of radical new technologies; Contract research for specific division problems**	**Mainstream product & process development; Incremental improvements**

Criteria for centralized vs. divisionalised R&D

A firm's main technological trajectory. Is the critical interface:

- **Between basic science and technology? (pharmaceuticals, chemistry) ⇛ Central lab + cooperation with universities**
- **Between R&D (and design) and production? (automobiles, aircraft) ⇛ Division**

How young is the field?

- **New fields like biotechnology, need to be sheltered for some time against the pressure of immediate valorisation ⇛ Central lab + cooperation with universities**

Corporate style:

- **Short-run profit maximization ('market-led strategy') leads to emphasis on divisionalised R&D ⇛ Division**

Uncertainty around R&D (1)

Planning and financial assessment of R&D projects is almost impossible, because:

- **Project outcomes are uncertain**
- **Different stages have different outcomes, requiring different methods of evaluation**
- **Many crucial variables depend on expert judgement (there are no precise figures to be fitted into a formula)**

Uncertainty around R&D (2)

Research by Edwin Mansfield shows that:

- **Managers and R&D workers can not predict accurately the development costs, time periods, markets and profits of R&D projects**
- **Underestimation of time and costs: 140-280% for incremental improvements; 350-600% for major new products**
- **More than half of all projects (and about half of R&D expenditures) are on failed projects**
- **R&D scientists often are over-optimistic in their estimates.**

Uncertainty around R&D (3)

How to deal with uncertainty?

- **Incrementalism: step-by-step modification of objectives and resources in the light of new evidence**
- **Use simple rules (transparency)**
- **Criteria for stopping a project should be made explicit from the beginning**
- **Use sensitivity analysis (E.g. 'What if costs double?')**
- **Try to reduce uncertainty before committing large sunk costs ('learning before doing').**
- **Recognize that different types of R&D require different evaluation criteria**

Uncertainty around R&D (4)

Three overlapping categories of R&D:

- **Knowledge building:** Monitoring of technological environment; inexpensive; questions: which options or threats emerge? Can we afford (not) to enter certain fields?
- **Strategic positioning:** Applied research and feasibility studies in order to reduce uncertainty and build in-house competence; live with high volatility of predictions and expectations; variety of evaluation methods that are more judgemental than rigorously quantitative.
- **Business investment:** Division-level decision about commitment of large resources (sunk costs!). Emphasis on user needs and marketing. Careful monitoring and control of progress. Tight control of external links (Joint Ventures, ownership).

Rationalists versus incrementalists

Victor Ansoff: rationalist school

Analogy with military experience:

- **Describe, understand and analyze environment**
- **Determine course of action**
- **Carry out action**

Rationalists versus incrementalists

Corporate equivalent of rationalist strategy:

SWOT

(Analysis of corporate Strengths and Weaknesses in the light of external Opportunities and Threats)

Weakness of rationalist strategy

Complex, fast changing environment, imperfect information:

- **"*The war in Vietnam is going well and will succeed*" (Robert McNamara, 1963)**
- **"*I think there is a World market for about 5 computers*" (T.Watson 1948)**
- **"*I cannot conceive of any vital disaster happening to this vessel*" (Captain of the Titanic, 1912)**

Incrementalist Strategy (1)

Make deliberate steps – measure and evaluate – adjust objectives (if necessary) and decide on next steps

Design – development – test – adjust design – retest – operate

Incrementalist Strategy (2)

Implications for corporate strategy:

(1) Corporatist strategy should be seen as a form of corporate learning, from analyses and experience, how to cope more effectively with complexity and change

(2) Successful management practice is never fully reproducible

Incrementalist Strategy (3)

Implications for strategy formation:

- **Explore implications of a *range* of possible (but uncertain) future trends**
- **Ensure broad participation and informal channels of communication**
- **Use multiple sources of information, debate and scepticism**
- **Expect to change strategies in the light of new (often unexpected) evidence**

Neoclassical topics relevant to innovation

- **Market failure through externalities and information asymmetry**
- **Transaction costs theory**
- **Sunk costs (exercises)**

Market failure due to externalities

- **Positive external effects lead to under-production or under-investment (examples: education, R&D, vaccinations)**

- **Negative external effects lead to over-production or over-investment (example: pollution)**

Cure:

- **Regulation by governments (emission standards, fees, tradable emission rights)**
- **Pigouvian subsidies or taxes**
- **Negotiation (only among small groups; Coase)**

Asymmetric information

Unequal or asymmetric information:

- **One market party knows more than the other.**

Examples:

- **Doctors versus patients;**
- **Insurance company versus a client;**
- **Lawyers versus clients**
- **Second hand cars ('lemons'); noisy flats**

The principal-agent problem:

Examples:

- **Managers versus shareholders**
- **Doctor and patient**
- **Lecturer and student**
- **Lawyer and client**
- **Supporting services in large conglomerates**
- **Supplier and buyer of intermediate products**

Key question:

- **Are the suppliers doing their best? (Cost reduction; quality) → They take advantage of information asymmetry!**

'Instrumental' rationality versus 'bounded' rationality

Instrumental rationality (neoclassical theory):

- **The choice of the best means to specified ends.**

Bounded rationality (Herbert Simon):

- **Decision-making is influenced by the limited cognitive capacity of actors. Firms are unable to maximise; they are '*satisficing*'; they stop searching for better solutions once they have found a satisfactory solution.**

Routines in evolutionary theory:

- **Definition: A routine is a regular and predictable behaviour pattern**

- **"Business decision making … is skilled behaviour, comparable to driving a car. It involves large amounts of learned skills, as well as limited amounts of immediate calculation."**

- **Management involves "internalized skills"; skilful behaviour has become "automatic", routed in the firm's history, culture and social milieu.**

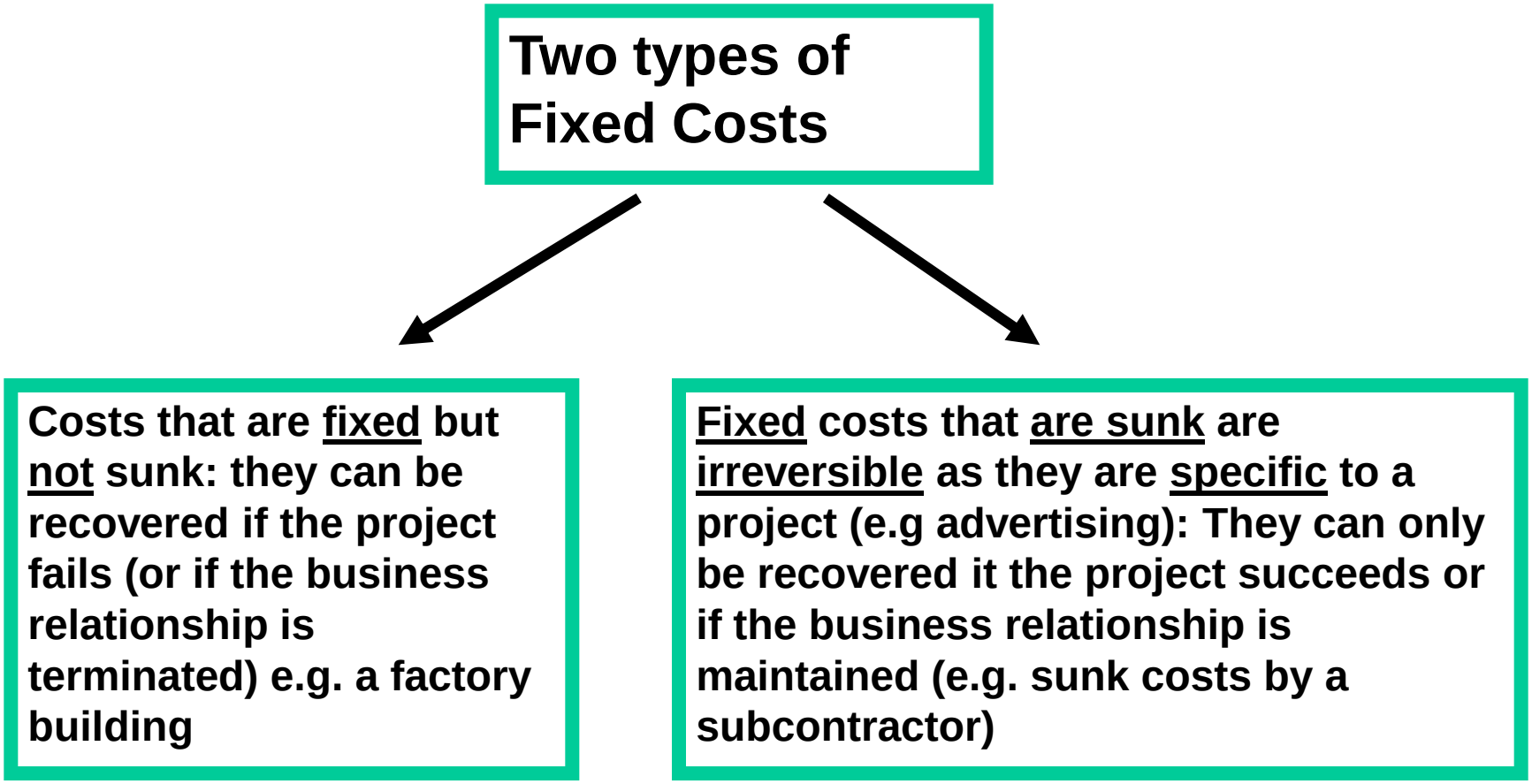
Dangers and limitations of routine behaviour

- **Danger:** Managers may display response patterns, drawing on internalized knowledge and skill, after the environment for which they were appropriate has changed.

- **History matters:** Cultures, experiences and "how we do things here" develop in time and constrain the present. They cause path dependency: past experience determines what the firm 'is good at'; it shapes ways of decision-making and closes off options. Firms may be trapped into inefficient behaviour by long-past influences and decisions.

- Routines are a kind of implicit contract, based on 'mutual understanding', 'custom' and 'practice' or 'shared expectations' (based on experience).

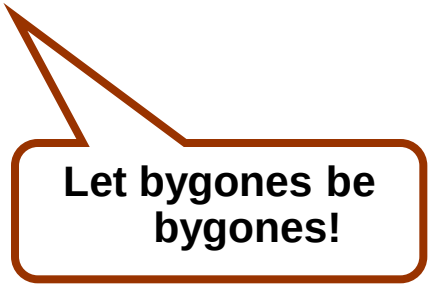
Decision-making with sunk costs ("sunk" = specific, irreversible)



Sunk costs have implications for decision-making, applying again the "decision in the margin" principle

→Imagine that you and your partner are planning a holiday in Spain or Greece. In a spontaneous impulse, you book an arrangement for two persons in Greece for 500 euro, all-in. In the evening, your partner tells you that he also booked something similar in Spain (for 800 euro) – unfortunately in the same week! The booking cannot be cancelled and you cannot sell it to somebody else, as the airplane tickets are on your names. You both feel that Greece, although cheaper, is probably nicer, as the hotel seems to look better.

You are free to choose: Greece or Spain?



Another example of decision-making with the sunk cost principle:

→As a subcontractor, you bought a special machine to produce front windows for the new Volkswagen Golf. You estimate that, at a price of 400 euro per window, you can regain your full (fixed and variable) costs, and earn a satisfactory profit. Your variable costs (raw materials, energy, wages, etc.) are 200 euro per window. In a tough price negotiation, Volkswagen offers you 220 euro per window ('take it or leave it!').

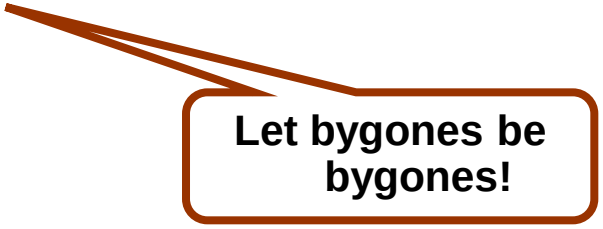
- **You take it or leave it?**

Let bygones be bygones!

Yet another example of decision-making with the sunk costs principle:

→**You are responsible for a Research & Development project with a budget of 2 million euro. The sales expectations of the new product to be developed would justify a maximum of 2.5 million spending on R&D. In the meanwhile, half of the budget is consumed and it turns out that, due to unforeseen difficulties, the project is more expensive than expected. A reliable estimate says that, above the one million that is already consumed, you need another two million euro to finalise the project.**

- **Make a 'stop or go' decision!**



General rule:

Let bygones be bygones! (accept your loss!)

- **Sunk investments from the past should play no role in your decision about the future! Just ignore them!**
- **The only rational consideration is: What are the costs and revenues from now on?**
- **In fact, this is a version of decision-making "in the margin": What counts is the decision about the next units.**

Limits to "Open Innovation": Transaction costs

Definitions:

External transaction costs:

- **All costs of transactions via the (external) market. These include all costs of collecting relevant market information, negotiating and preparing contracts, monitoring whether partners fulfil contracts, and the taking of sanctions if they do not.**

Internal transaction costs:

- **Costs of coordination and management of transactions within hierarchical organisations**

The problem behind transaction costs:

→In principle, every activity of a firm could be contracted out

Question:

→Which activities should be contracted out (market transaction) or done internally (hierarchical transaction?) →The famous 'make-or-buy?' problem

Questions:

- Why not contracting out everything?
- Why do (large) organizations exist at all?
- Why does not everybody have her own company?

A simple criterion for handling the 'make-or-buy' problem:

- **If costs of internal, hierarchical transaction are higher than external (market) transaction costs, then contract out ('buy')**

- **In the opposite case: 'make'**

But this requires some refinements …

Factors favouring 'make' (instead of 'buy'):

- **The existence of uncertainty (e.g. in judging the quality of a good or service) creates strong possibilities of opportunistic behaviour which increase costs and risks of market transactions**

- **Asset specificity: Assets can have higher economic value inside than outside a particular transactional relationship, e. g. sunk costs by a subcontractor; or dependence on a specialised supplier who achieves some monopoly power. Opposite case: if there are many suppliers of standardized goods, market transactions are to be preferred.**

Factors favouring 'make' (instead of 'buy'):

- **Frequency of transaction: Frequency influences the relative costs of market versus hierarchical governance. Repeated market transactions among a small number of participants offer wide possibilities of opportunistic behaviour**

- **Turbulence in an environment may require frequent changes of contracts for market transactions and struggle about how to interpret incomplete contracts**

- **Incentives: Where other contract parties have incentives to act against the interests of the contracting firm, costs of contracting, control and sanctions can multiply (e.g. contracting out R&D)**

Summarizing:
Is there an imperfect market?

In other words, is there:

- **Incomplete information? (quality of products)**
- **Turbulence? (incomplete contracts)**
- **Does the other party have market power?**
- **… or possibilities of opportunistic behavior?**
- **Are you vulnerable as you incurred sunk costs?**
- **Has the other party of motive for acting against your interests? (e.g. knowledge leaking?)**

→ In all those cases: don't contract out!

… and when should we contract out?

Ideal situation:

- **The other party operates in a market with transparent quality: many suppliers of standard goods or services; strong competition (e.g. cleaning services)**

The big advantage of contracting out:

- **If you chose for "make" (rather than "buy"), you have the typical *principal-versus-agent* problem with supporting services:**

- **Heads of departments tend towards budget maximization!**
- **Are they doing their best? (growing overhead costs!)**
- **Heads of departments can use information asymmetry (they know more about their work than a CEO does!**

Benchmarking through contracting out can help!

Finally: There is not one clue to successful innovation

The literature emphasis the need for an integrated approach to innovation management

An example of a good book:

J. Tidd, J. Bessant & K. Pavitt: *Innovation Management*, Wiley, 3rd ed. 2005

Problems with partial views of innovation (1)

If innovation is only seen as …

- **Strong R&D capability**

… the result can be:

- **Technology fails to meet user needs**

Problems with partial views of innovation (2)

If innovation is only seen as …

- **The province of specialists in R&D laboratories**

***… the result can be*:**

- **Lack of involvement and knowledge / experience from others (e.g. clients, market research)**

Problems with partial views of innovation (3)

If innovation is only seen as …

- **Understanding and meeting customer needs**

… the result can be:

- **Lack of technical progression (users are conservative; they demand what they know)**

Problems with partial views of innovation (4)

If innovation is only seen as …

- **Technology advances**

… the result can be:

- **Producing products which customers do not want; designing (over-engineered) solutions which fail to meet user needs**

Problems with partial views of innovation (5)

If innovation is only seen as …

- **The province only of large firms**

… the result can be:

- **Weak small firms with too high a dependence on large customers**

Problems with partial views of innovation (6)

If innovation is only seen as …

- **Only about "breakthrough" changes**

… the result can be:

- **Neglect of economic potential of incremental innovation**

Problems with partial views of innovation (7)

If innovation is only seen as …

- **Only associated with key individuals**

… the result can be:

- **Failure to utilize creativity of your entire organization**

Problems with partial views of innovation (8)

If innovation is only seen as …

- **Only internally generated**

… the result can be:

- **'Not invented here' effect**

Problems with partial views of innovation (10)

If innovation is only seen as …

- **Only externally generated**

… the result can be:

- **Little internal learning; dependence on others**

Problems with partial views of innovation (11)

If innovation is only seen as …

- **Only concerning single firms**

… the result can be:

- **Neglect of networking**